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REPORTS OF OBSERVATORIES.

LICK OBSERVATORY, MT. HAMILTON, CALIFORNIA.

The last number of these *Publications* contains a full account of the Crocker Eclipse Expedition dispatched to Flint Island to observe the total solar eclipse of January 3, 1908. It is therefore unnecessary, in this record of observatory activities in 1907, to refer to the subject, further than to say that the preparations at Mt. Hamilton and on Flint Island, and travel to the island, occupied the time of Messrs. CAMPBELL, PERRINE, AITKEN, and ALBRECHT during the three or four closing months of the year. It is expected that the results of this very successful expedition will all be presented in these *Publications* from time to time, as ready, in 1908. Professor LEWIS, of the Department of Physics, University of California; Professor BOSS, in charge of the U. S. Naval Observatory, Pago Pago, Samoan Islands; Mr. MERFIELD, of the Sydney Observatory; and Consul and Mrs. DREHER, of Papeete, Island of Tahiti, were valued members of the expedition.

The observations with the meridian circle in charge of Astronomer TUCKER, aided by Carnegie Assistant R. F. SANFORD, were confined principally to the completion of two years' work on a programme for determining the accurate positions of stars based on fundamental methods. About 1900 observations on this programme were secured during the year. The stars on the programme are distributed mainly between 37° north and 37° south declination. Special stars are included in the programme for the purpose of determining the observer's personal errors as affected by his position while making the observations, and by the direction of the apparent motion of the stars through the field of view. Other stars for the investigation of atmospheric refraction effects were selected from 60° to 65° north declination, and observed at upper and lower culminations. These will give observed effects down to more than 80° zenith distance in the north, and selected southern stars having similar zenith distances were observed for the same purpose. The reductions of the observations for the two years are well advanced.

Mr. TUCKER's problem is complicated by the existence of a daily period in the azimuth of the instrument, as shown clearly by both the first and the second year's observations. The meridian mark (mire) appears to give consistent results for periods of considerable length, and the diurnal azimuth variations observed are clearly due to changes in the position of the instrument itself. It is only by making observations at all hours of the day that the azimuthal changes can be resolved into their component parts and the necessary corrections be applied to the observations.

During the year, Volume X, *Publications of the Lick Observatory,* containing Professor TUCKER's observations with the meridian circle obtained in 1901-6, was published and distributed. The principal contents of the volume consist of a catalogue of 2798 zodiacal stars. The stars in the list were selected by Sir DAVID GILL as a basis for heliometer measures of the Moon and planets. The volume also contains observations of other special lists of stars, as well as a discussion of the graduation errors of the circles.

In the year 1907 a special list of stars was observed for Dr. L. DE BALL, of Vienna, for use in his determinations of stellar parallax. The right ascension of the Moon was observed on several nights in the fall and winter of 1907 to determine the effect of existing errors in the Moon's ephemeris position on the predicted times for the total solar eclipse of January 3, 1908. Mr. TUCKER found that the Moon was more than 0.4 of a second east of its published position. This discrepancy would cause the eclipse to occur about twenty seconds of time earlier than predicted.

The optical system of the Crossley reflector consisted exclusively of the 36½-inch silver-on-glass mirror, which has a ratio of aperture to focal length of 1 : 5.8. This ratio is not suitable for the collimator of a spectrograph, and, likewise, the scale of stellar photographs is too small to admit of the very accurate observations required in parallax determinations. Quite extensive investigations by Dr. PERRINE and Dr. ALBRECHT established clearly the desirability of reducing the magnitudes of unavoidable errors by increasing the equivalent focal length. To this end Mr. F. G. PEASE, expert optician to The Scientific Shop, in Chicago, spent four weeks on Mt.

Hamilton in the summer of 1907, figuring a 9¾-inch hyperboloidal mirror for the Crossley reflector, in order to convert the telescope into the Cassegrain form. A third mirror, with flat surface, is mounted diagonally with reference to the incident light, immediately in front of the parabolic mirror, in order to direct the beam through the side of the telescope-tube near its lower end. The equivalent focal length has been increased by the combination to about seventy feet. Professor PERRINE, who designed the necessary mechanical additions, and assisted Mr. PEASE in the tests, is hoping promptly to utilize the telescope, thus modified, in the development of stellar-parallax methods, and Mr. CAMPBELL is planning for spectrographic work on certain especially interesting types of stars in the near future.

The most extensive investigation under way is that of determining the radial velocities of the brighter stars by means of the Mills spectrograph attached to the 36-inch refractor, in accordance with a programme entered upon by Mr. CAMPBELL in 1896. This programme hopes to include all the stars whose photographic magnitudes are equal to or brighter than 6.0, lying north of —25° declination, with the addition of essentially all of the stars brighter than the fifth magnitude between —25° and —30° declination. The number of stars on the list is approximately 750, but a certain number of these are not amenable to accurate observation, for the reason that their spectra do not contain sharply defined lines. The number of spectrograms secured with the 3-prism Mills instrument in 1907 was approximately 500. The total number of spectrograms obtained up to January 1, 1908, was 5,086. The number is not increasing so rapidly in recent years as formerly, because the greater part of our attention is now given to fainter stars requiring longer exposures. It is interesting to note that we have found it possible to use wider slits and, at the same time, obtain spectra of sufficient purity to permit accurate measurement. In this way we are able, under average conditions of seeing, to obtain good spectra of stars of 6.0 photographic magnitude in from two hours to two and a half hours.

Of the 500 plates exposed in 1907, practically all have been measured and reduced approximately, and fifty definitively. The observing in this programme was carried on by Messrs.

CAMPBELL, WRIGHT, MOORE, and ALBRECHT. Since November 1st, Mr. H. C. PLUMMER, Fellow, has also observed regularly. Occasional assistance was rendered by Carnegie Assistant K. BURNS, by Fellows J. C. DUNCAN and E. A. FATH, and by visiting astronomers Dr. C. A. CHANT and Dr. A. B. TURNER.

During the year eleven spectroscopic binaries were discovered in the course of the regular observing programme—one by Mr. CAMPBELL, one by Mr. PLUMMER, and nine by Mr. MOORE.

Dr. MOORE is making a new investigation of the orbit of the variable binary-star *δ Cephei,* forty-one 3-prism spectrograms having been secured in 1907 for this purpose.

Two hundred and fifty definitive measures of 3-prism spectrograms, made by Carnegie Assistant NEWKIRK up to the date of his departure in September, have been reduced by Miss LEAH ALLEN, Carnegie Assistant.

The measures and reductions of all spectra taken with the Mills spectrograph between August, 1907, and July, 1903, were completed by Carnegie Assistant BURNS in July, 1907, as the result of his three years' work. Mr. BURNS's extensive spectrographic investigation of the rotation of *Venus,* while not yielding positive evidence as to the rotation period of that planet, was valuable in making clear the elements of the problem and in indicating the desirable features of apparatus and methods for obtaining a satisfactory solution.

Spectrographic observations of *Polaris* obtained in the past two years show that the velocity of the bright component in the line of sight is slowly approaching that observed by Mr. CAMPBELL in 1896. The long period of this interesting triple star cannot now be defined, but it is probably between twelve and twenty-five years.

Dr. A. B. TURNER, of the College of the City of New York, completed his investigation of the orbit of the spectroscopic binary *ω Draconis,* which he carried on during the summer vacations of 1906 and 1907.

Dr. ALBRECHT's paper on "A Spectroscopic Study of the Fourth Class Variable Stars, *Y Ophiuchi* and *T Vulpeculæ,*" completed in 1907, brought out the fact that, in the *δ-Cephei* class of variables, a relation apparently exists which promises to be extremely significant in determining why these stars vary. He found, in the ten stars of this class thus far investigated, that the maximum of brilliancy occurred at or very near the time when the bright component of each of these binary systems was moving toward the observer. No exception to this rule has been noted. Inasmuch as the ten observed stars are distributed through a considerable area of the sky, it is surprising to find that the time of greatest brightness is apparently dependent upon the observer's position in space. It may easily transpire that this is one of the most significant discoveries concerning variable stars made in recent years.

The work of the D. O. Mills Expedition to the southern hemisphere, interrupted in 1906 while numerous improvements in and additions to the apparatus were made, and more or less by the great earthquake of August, was prosecuted vigorously by Astronomer CURTIS and Assistant PADDOCK throughout the year 1907. A large number of stellar spectrograms were secured with the 3-prism, 2-prism, and 1-prism instruments. All of these were measured and reduced provisionally, and many of them definitively. The orbits of several interesting spectroscopic binary stars were investigated and published. The diurnal range of focal length, caused by rapid changes of temperature, formerly so troublesome, has been eliminated by Dr. CURTIS through the use of the refrigerating apparatus recently described in these *Publications*.

The measurement and reduction of the 800 spectrograms obtained during the original two-year period of observation by Professor WRIGHT and Assistant PALMER were completed on Mt. Hamilton about the middle of 1907 by Messrs. WRIGHT and ALBRECHT. Both have made extensive studies of systems of normal wave-lengths to be used as a basis for applying the final corrections to the southern hemisphere results.

Dr. ALBRECHT continued during the year, as time was available, his study of the effective wave-lengths of spectrum lines as dependent upon spectrum type.

Dr. AITKEN has continued the double-star survey of the northern sky, according to the systematic plans described in former reports. During the year 1907 he examined about 8,500 stars, down to the 9.0 magnitude inclusive, with the 12-inch and 36-inch refractors, and 250 of these stars were found to be double, all the pairs having distances less than five seconds. This number is smaller than that reported in 1906, partly because of unusually bad observing conditions in the first half of the year and partly because of absence on the eclipse expedition. These discoveries include a number of pairs likely to prove of more than ordinary interest. We may mention the very close and bright pairs κ *Ursæ Majoris* (4.5 magnitude) and ν^2 *Bootis* (5.0 magnitude). It is expected that this survey, as carried on at Mt. Hamilton, will extend to —22° declination. Fully eighty-five per cent of the survey has been completed, and, given ordinary observing conditions, this section of the work should be finished in the summer of 1910. Prior to January, 1908, more than 3,000 close doubles had been discovered, as one result of the survey—1,300 + by Professor HUSSEY and 1,700 by Professor AITKEN.

It is scarcely necessary to say that the great value of this notable survey lies not in these discoveries themselves, but in the enormously increased opportunity which the discoveries will afford in the future study of double stars in particular and of the structure of the sidereal universe in general. Holding the requirements of this study in mind, the systematic qualities of the search are rigidly maintained, and at least two satisfactory micrometer measures of each pair are secured, as promptly as practicable, before announcing the discovery. It is hoped, for example, that future computers of their orbits will have the great advantage of an accurate discovery-position in every case.

About one hundred of the more important and difficult of the well-known double stars are kept under observation, measures being made as often as they are needed to improve our knowledge of the orbital motion. To refer to only one pair: Dr. AITKEN'S measures of the binary 13 *Ceti,* discovered by HOUGH in 1886, have enabled him to establish that the revolution period of this system is only 7.4 years; next to that of δ *Equulii,* the shortest period known.

Micrometer observations of the satellites of *Uranus* and of the inner satellites of *Saturn* were continued by Dr. AITKEN with the 36-inch refractor. Eclipses of *Saturn's* satellites were observed on six nights, and close attention was given to the phenomena presented by *Saturn's* rings, whose plane passed through the Earth twice and through the Sun once during the year. The causes of the curious bright knots, or condensations, observed in the rings, here and elsewhere, are undergoing discussion in several journals, and our knowledge of the structure of the rings promises to be increased.

Micrometer observations of comet positions have been obtained as follows:—

Comet *a* 1907,	2 nights,	Aitken
Comet *a* 1907,	4 “	Fath
Comet *b* 1907,	6 “	Aitken
Comet *c* 1907,	1 “	Aitken
Comet *d* 1907,	4 “	Aitken
Comet *d* 1907,	12 “	Duncan
Comet IV 1905,	5 “	Aitken
Comet *e* 1907,	7 “	Duncan

Comet 1905 IV, discovered by Kopff in March, 1906, and later found on photographic plates taken at Heidelberg in January, 1905, was under observation for a longer consecutive time than any previous comet.

Micrometer positions of asteroids have been obtained as below:—

Nemesis (128), 2 nights, Aitken.

Mr. Fath, Fellow, began an extensive study of the zodiacal light, with special reference to polarization effects and the character of its spectrum. One spectrogram exposed by Mr. Fath on several successive nights, and another exposed for Mr. Fath's use by Mr. Duncan, recorded the spectrum in good strength. The study will be renewed on Mr. Fath's return in the summer of 1908. Interpretation of the observations will be deferred until more data are available.

Observations of *Jupiter's* satellites VI and VII, with the Crossley reflector, were secured by Messrs. Perrine and Albrecht.

The application of electric power to moving the Crossley dome and to winding the clock, in combination with the splendid clock-driving, has rendered unnecessary the services of an assistant to the Crossley observer.

Good progress was made in the preparation of heliogravure plates of Professor Keeler's nebular photographs, with reference to their publication in volume form. To secure satisfactory reproductions by mechanical processes has been a long struggle, so great are the difficulties encountered; but it is confidently expected that the volume will be ready in 1908. This arduous task has been in Dr. PERRINE'S charge.

Comet *d* 1907, discovered by DANIEL, was the brightest comet that had been in good observing position since 1893. Advantage was taken of this fact to secure a splendid series of photographs. Exposures were made by Mr. DUNCAN on thirty-six nights, from July 10th to September 12th, seventy-one negatives in all. These photographs, forming as nearly continuous a series as the weather and the moonlight permitted, exhibit admirably the progressive changes occurring in the head and tail as perihelion was approached, and likewise several interesting phenomena of an irregular character. In general, the changes were very rapid. It is probable that the tails of one night were entirely replaced by tails composed of new matter on the following night. A noteworthy fact was that whenever any of the streamers appeared as curves, their convex sides were turned toward the other streamers, suggesting strongly that the particles in the tails repel each other. Only the negatives of July 10th and 11th recorded well-defined condensations in the tails. Fortunately, Professor BARNARD obtained a photograph of the comet on July 11th, at the Yerkes Observatory, a copy of which he kindly supplied to us. In the 2^h 25^m elapsing between the taking of the Yerkes and Lick plates, the displacement of the prominent condensation was very marked. Although the nucleus of the comet was approaching the Sun, the condensation receded from the Sun. Mr. DUNCAN found its velocity away from the nucleus to be 44^{km} per second, and from the Sun 15^{km} per second. Several less definite structures were observed on later plates. Two exposures having been made here on the same night, whenever possible, Mr. DUNCAN was successful in detecting outward motion in several cases; and the velocity of recession was always the greater for greater distances from the nucleus. This is as it should be, assuming their motion to be due principally to a continuously acting repulsive force emanating from the nucleus, or from the Sun, or from both.

Polarization observations of the comet, made by Messrs. DUNCAN and CAMPBELL, seemed to show that the proportion of polarized light decreased rather rapidly as the comet approached the Sun; indicating that its light at first consisted largely of diffused sunlight and later mostly of light inherent to the comet or of sunlight reflected to us by large particles forming the nucleus.

The spectrum of the comet was studied by Mr. CAMPBELL. It was at first almost free from the bright bands of carbon and cyanogen, but in late August and early September these became very prominent. The best spectrograms showed the spectrum of the nucleus to be a close approximation to the solar spectrum (reflected sunlight, apparently not polarized strongly), and the spectrum of the coma to consist largely of a great number of bright lines.

The photography of comets, applied with great success, first by Professor BARNARD at the Lick Observatory and subsequently by observers at various stations, has made clear the fact, undoubtedly very significant, that the tails of these bodies undergo exceedingly rapid changes. It is not too much to hope that a thorough study of these internal changes will shed strong light on the origin, composition, and physical conditions of cometary bodies. Bright comets, naturally, keep to the region of the sky immediately surrounding the Sun, and for this reason it is seldom practicable for the same observer to secure more than one good photograph per night. In these days of astronomical co-operation, we cannot find a subject more worthy of co-ordinated effort on the part of different observatories than that of comet photography. It is high time that such an organization be perfected, to care suitably for the bright comets of the future. The interests of observers provided with telescopes suitable for photographic comets, both in this country and abroad, should be enlisted and organized, so that, as a comet is successively in position for these observers, covering a wide range of terrestrial longitudes, photographic records will be obtained suitable for subsequent comparison.

The general plans for the observatory were made in the late 70's and executed in the early 80's, at which time astronomers did not realize the important part that photography was destined to play in their researches. Consequently, when the institution was opened, on June 1, 1888, it did not possess suitable apparatus and rooms for taking celestial photographs and for their measurement and study. Director HOLDEN proceeded energetically and wisely to transform the equipment to meet photographic requirements. Fortunately, gifts from outside sources, and such small sums as could be spared from the maintenance funds, provided for photographic telescopes, spectrographs, and measuring microscopes. Space suitable for the storage and study of photographs has been a pressing need, and the successive annual reports of Directors HOLDEN, KEELER, and CAMPBELL have drawn attention to this need. The last two legislatures appropriated small sums to begin such a building. With these funds a section of the building was erected in the late fall of 1907, of reinforced concrete. It includes three storage vaults on the first floor, and an enlarging room fifty feet long on the second floor: one third the space of the finished building as planned, erected at one half the total cost. It is hoped that the next Legislature will provide for its completion, in 1909.

The installation of the electric plant, begun under great and unnatural difficulties immediately following the earthquake and fire of April, 1906, was completed in June, 1907. A twenty horse-power gasoline engine, using distillate, is directly connected to the dynamo, which charges a storage battery of 128 cells, each having a capacity of 200 ampere hours. The battery serves as a reservoir of power, to be drawn upon as required. Apart from current for producing comparison spectra, maintaining the spectrographs at constant temperatures, lighting micrometers, and for other purely scientific work, it is drawn upon to turn the domes of the 36-inch refractor and the Crossley reflector, to wind their clocks automatically, to run the machinery in the instrument-making and carpenter shops, to operate two pumps in the water systems, to saw fuel for the community, and to illuminate all the buildings. The entire plant is operating satisfactorily, and is a great addition to the resources of the observatory. In particular, the use of motors in winding clocks (automatically) and turning domes has perceptibly increased the observing efficiency.

A considerable list of minor scientific results and additions to equipment should, for completeness, be mentioned, but space is lacking.

W. W. CAMPBELL,
Director.